

**Phonetic Characteristics of Levantine Arabic Geminates
with Differing Morpheme and Syllable Structures**

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Abstract: Phonologists distinguish two types of geminates: tautomorphemic (belonging to a single morpheme and composed of one set of phonological features) and heteromorphemic (belonging to separate morphemes and composed of two identical sets of phonological features). If there is a phonetic difference between geminates due to the fact that the second type has two separate sets of features while the first type has only one set, it would likely be cued by differences in duration or by movement during the duration of the consonant. Arabic provides a means for comparing these types of consonants since it has both occurring in a variety of morphological affiliations as well as in contrasting surface phonological positions. A pilot study and a larger experiment were performed with speakers of Levantine Arabic to compare these conditions. No significant differences in duration occurred, and several occurrences of both types of geminates had apparent releases during their durations. These results show that no phonetic difference was found between heteromorphemic and tautomorphemic geminates in Levantine Arabic. On the other hand, a phonetic difference was found linked to syllable structure: tautosyllabic and heterosyllabic geminates had different mean durations as compared to their single counterparts. Since the structure that has been posited by phonologists (association of phonological features with C and V slots) does not capture these differences, it is therefore necessary to refer to syllable structure (= association of phonetic features with syllable slots) in order to represent these phonetic differences.

1. Introduction

Phonologists have recently distinguished two types of geminates based on evidence that geminates with different phonological structures behave differently in certain phonological and morphological situations (cf. Hayes 1986, McCarthy 1986, and the references listed in these articles). Tautomorphemic geminates occur within a single morpheme and have one set of phonological features linked to two consonant slots. They are also known as "monomorphemic," "underlying," or "true" geminates. Heteromorphemic geminates are formed by concatenation of morphemes and have two identical sets of phonological features linked to two consonant slots. They are also known as "derived" or "fake" geminates.

One of the differences between these types of geminates has been pointed out clearly by McCarthy (1986:210-219), who discusses a number of phonological and morphological situations in which tautomorphemic geminates act like one segment rather than like two. He argues that, therefore, the two consonant slots of tautomorphemic geminates are associated with only one underlying set of phonological features (= "melodic segment") rather than with two as the two consonant slots of heteromorphemic geminates are.

Other differences have been articulated clearly by Hayes (1986:326-33), who discusses differences between these types of geminates in a number of phonological situations. He shows that tautomorphemic geminates are never split by epenthesis (they "have integrity"), while heteromorphemic geminates can be split by epenthesis (they do not "have integrity") if they are not formed by total assimilation. Also, tautomorphemic geminates are never affected by phonological rules whose descriptions otherwise fit them (and so would be expected to apply to them) if the rules specify that the affected segment be associated with only one consonant slot (they "respect inalterability"), while heteromorphemic geminates in this situation are affected by such phonological rules (they do not "respect inalterability"). Furthermore, Hayes points out that heteromorphemic geminates derived by total assimilation have the surface structure of tautomorphemic geminates and exhibit their characteristics. He notes that none of these characteristics is surprising when it is accepted that these geminates which act differently have different phonological structures. In fact, the differences in behavior fall out from the differences in structure.

In order to capture the differences in phonological structure, these two types of geminates are often schematized as in (1) and (2). (1) shows that tautomorphemic geminates and heteromorphemic geminates derived by assimilation are represented as consisting of one set of phonological features linked to two consonant slots. (2) shows that heteromorphemic geminates not derived by assimilation are represented as consisting of two sets of phonological features, each linked to a separate consonant slot.

(1) Phonological Representation of Tautomorphemic Geminates and Heteromorphemic Geminates Derived by Assimilation

CC
 ↓
 [F] ([F] = any set of phonological features which comprise a segment in a language, often abbreviated with the phonetic symbol; e.g., [t])

(2) Phonological Representation of Heteromorphemic Geminates

CC
 ↙ ↘
 [F] [F]

Older phonetic studies have provided evidence that there are some possible phonetic correlates of these phonological differences, although not couched in these phonological terms and not specifically addressing this issue. Some conflicting results have been obtained, but the fact that positive results have been obtained by some studies shows that phonetic differences may exist between different types of geminates--although perhaps in specific conditions that have yet to be identified.

Conflicting results have been obtained for movement characteristics during the duration of heteromorphemic and tautomorphemic geminates. Several studies have found heteromorphemic geminates to have two peaks or phases in their amplitude curves (Stetson 1951: heteromorphemic geminates

in English) and in their amplitude curves and tongue shapes (Delattre 1971: English, German, French,¹ and Spanish), but tautomorphemic geminates to generally have only one peak or phase in these (Hegedüs 1959: Hungarian had only one peak; Delattre 1971: Spanish word-initially and German medially and word-finally had only one phase while Spanish medially had one phase in less than half the tokens but two phases in more than half). Other studies, on the other hand, have found heteromorphemic and tautomorphemic geminates not to differ with respect to average number of peaks in their air pressure curves, articulatory pressure curves, or EMG traces. Evidence for this is found in studies which have shown both types of geminates to generally have at least two such peaks but the corresponding single consonants to generally have only one such peak (Poirot in Rousselot 1897-1901 and 1901-1908:1087: tautomorphemic geminates vs. single consonants; and Lehiste, Morton, and Tatham 1973: heteromorphemic and tautomorphemic [two lengths] geminates compared to single consonants and to each other in Estonian). It should be noted, though, that contrary to Delattre (1971), Lehiste, Morton, and Tatham (1973) found the slightly greater number of EMG peaks in English heteromorphemic geminates not to be significantly greater than the number of peaks in corresponding single consonants. It should also be noted that Rousselot (1891, 1897-1901 and 1901-1908:351 and 1087, and 1913:77) found only two tautomorphemic geminate consonants which showed two peaks in the air pressure and articulatory pressure curves in Swedish and none in Gallo-Roman. However, Stetson (1951:61) believed that Rousselot's results could not be relied on because his equipment was not very sensitive.

Conflicting results have also been obtained for the duration characteristics of heteromorphemic and tautomorphemic geminates. A number of studies have found both types of geminates to be about one and one-half to two times as long as the corresponding single consonants for the shortest length distinction within a language (geminate to single consonant in languages with only one length distinction, and short geminate to single consonant in languages with more than one length distinction) (Rousselot 1891: tautomorphemic geminates in Gallo-Roman; Josselyn 1901:222ff.: tautomorphemic geminates in Italian; Stetson 1951: heteromorphemic geminates in English; Delattre 1971: tautomorphemic geminates in German and Spanish, and heteromorphemic geminates in these languages, English, and French; and Lehiste, Morton, and Tatham 1973: short tautomorphemic geminates in Estonian). A recent phonetic study (Hankamer and Lahiri 1986) also found no significant difference in length between tautomorphemic geminates and heteromorphemic geminates in Turkish and Bengali. All these results point to the conclusion that heteromorphemic and tautomorphemic

¹My classification of one of the sets of French tokens--the conditional present--as containing heteromorphemic rather than tautomorphemic geminates depends on the morphological analysis of the tokens mourrait, courrait, and acquerrait as containing an infixed -r- rather than a stem which ends in -rr-. The latter is the traditional account (cf. Judge and Healey 1983:221, 259n.2; Ollivier 1978:165-66), while the former is based on formal linguistic analysis (cf. Judge and Healey 1983:216, 259n.2). I have chosen to follow the linguistic analysis. Following the traditional analysis would change the conclusions made here since half the French tokens with two phases in Delattre's study would then contain tautomorphemic geminates.

geminate do not differ in their duration characteristics since they both differ by the same amount in duration from their single counterparts. However, Lehiste, Morton, and Tatham (1973) obtained results contradictory to this in their study of English, in which English heteromorphemic geminates did not differ significantly in length from their single counterparts. Also, the two older phonetic studies discussed here which investigated both heteromorphemic and tautomorphemic geminates in the same study showed the tautomorphemic geminates to sometimes be significantly different in duration from the corresponding heteromorphemic geminates in the language (Delattre 1971: comparisons of both types of geminates to the corresponding single consonants showed this for Spanish word-initially and medially, and German word-finally, although not for German medially; Lehiste, Morton, and Tatham 1973: comparisons of heteromorphemic geminates to long tautomorphemic geminates in Estonian showed this for one of the two sets of tokens).

The evidence described above of possible phonetic differences between different types of geminates is in contrast to assumptions currently made by phonologists, who assume that, despite the different phonological structures, there is no phonetic difference between different types of geminates. For example, McCarthy (1986:250) states that "we usually find that languages make no phonetic distinction between hetero- and tautomorphemic geminates, despite their different melodic representation." It has been suggested that the presence vs. the absence of distinguishing phonetic characteristics of heteromorphemic and tautomorphemic geminates may be language-specific (Lehiste, Morton, and Tatham 1973:147) since a native speaker of Estonian and a native speaker of English each carried her native-language patterns of duration and number of peaks in EMG traces over to the other language. However, the existence of contradictory results for English (by Stetson 1951 and Delattre 1971, as described above) and the negative results of Hankamer and Lahiri (1986) suggest that there may also be other reasons for differences in phonetic characteristics of geminate consonants. These may be differences between speakers within a language or differences in language structure according to the number and type of contrasts (e.g., single, short tautomorphemic, long tautomorphemic, and heteromorphemic consonants in Estonian vs. only single and heteromorphemic consonants in English) which exist in the consonants of the languages. Much more study is needed before possible phonetic differences due to variation between speakers or language types can be pinpointed accurately. But the existence of the contradictory results described here shows that the existence or non-existence of possible phonetic differences between different types of geminates has not yet been determined.

Since duration and movement are the major characteristics for which differing results have been obtained in studies of geminates, this study investigated these characteristics for various types of geminates in yet another language--Arabic--by investigating the Levantine dialect. Arabic is a good candidate for such study because it has not only tautomorphemic and heteromorphemic geminate consonants² but also tautosyllabic and

²Neither traditional analyses nor recent linguistic analyses of Arabic (cf. Brame 1970; McCarthy 1979, 1981) distinguish by terminology these types of geminates. These analyses refer to all of the lengthened consonants with the same term--as doubled or geminate consonants--and also represent all of

heterosyllabic geminate consonants. Geminates in Levantine Arabic thus occur in a variety of morphological affiliations as well as in contrasting surface phonological positions. This made possible an investigation for phonetic similarities and differences in terms of both morphological and phonological structure. In terms of morphological structure, Arabic has tautomorphic geminate consonants word medially (e.g., [kætʃtəb]) and finally (e.g., [fətt]), and heteromorphic geminate consonants across morpheme boundaries (e.g., [t+t+əbʃ]) and word boundaries (e.g., [nəbət#təxt] and [rufət#təxt]), including some which are assimilated (e.g., [d+d+əər] < /d+t+əər/ and [t#təxt] < /ʔl#təxt/). In terms of surface phonological structure, the tautosyllabic and heterosyllabic geminate consonants in Arabic both include some tautomorphic and some heteromorphic geminates. Tautosyllabic geminates include tautomorphic [fətt] as well as heteromorphic [t+t+əbʃ] and [t#təxt]. Heterosyllabic geminates include tautomorphic [kætʃtəb] and heteromorphic [nəbət#təxt] and [rufət#təxt]. This second contrast is especially interesting since it seems likely that if there is a regular phonetic difference between different types of geminates, it would more likely reflect differences at the surface phonological level than at the abstract morphological level.

This investigation examined these two sets of contrasting types of geminate consonants in Levantine Arabic by comparing them to minimally contrasting short consonants. It was expected that if there is a phonetic distinction between tautomorphic and heteromorphic geminate consonants or between tautosyllabic and heterosyllabic geminate consonants, it would likely be cued by durational differences or by the absence (which would suggest no movement) vs. the presence (which would suggest movement),

them as being composed of two identical consonants (the recent analyses including some justification in terms of their overall frameworks). However, these lengthened consonants are structurally two different types of consonants on morpho-syntactic grounds since the first do not cross morpho-syntactic boundaries whereas the second do. Therefore, the first are treated here as tautomorphic geminates, and the second are treated as heteromorphic geminates. Although I have argued that McCarthy's (1979, 1981) analysis of Arabic is inelegant in its treatment of the morphological differences in Arabic, thereby obscuring lexical similarities of the various binyanim (see Miller 1986), it should be noted that a strength of McCarthy's analysis is that the structure it proposes for Arabic does implicitly recognize the morphological difference between heteromorphic and tautomorphic geminates by representing them differently from each other at the autosegmental level. For the geminates treated in this paper, for example, it places the Form VIII reflexive infix -t- on a separate autosegmental (= morphological) tier from the root consonants (which it sometimes assimilates to, thus forming a geminate consonant) and has the infix and the root consonants associate to different consonant slots in the prosodic template, while it places the geminate consonants in Form II and in geminate roots on the same tier by representing them as composed of one melodic element which associates with two consonant slots in the prosodic template. However, even though McCarthy's (1979, 1981) analysis represents these types of consonants as different structurally at the autosegmental level, the terminology is misleading since it terms both types of geminates as simply geminates and does not label them as different in terms of their CV structures.

respectively, of a release spike during the duration of the consonants since the first member of each pair is one unit at that level of structure (tautomorphemic and tautosyllabic), while the second member of each pair is composed of two units (heteromorphemic and heterosyllabic).

A pilot study found that the difference between tautomorphemic geminates and heteromorphemic geminates in a small corpus was not cued systematically by either of these characteristics. This suggested that there may not be a phonetic difference between these types of geminate consonants. The results also suggested the possibility that tautomorphemic geminate consonants may not be as closely joined as the phonological studies claim since one instance of a medial tautomorphemic geminate showed an apparent release spike in the middle of the closure duration--which may be evidence of rearticulation³--as did three instances of heteromorphemic geminates across word boundaries. Figure 1 shows the spike which occurred in the middle of the tautomorphemic geminate duration.

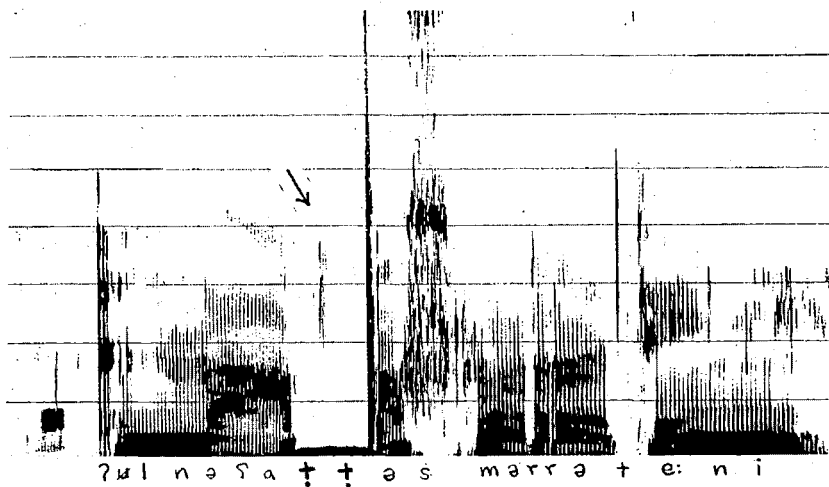


Figure 1. An apparent release spike--which may be evidence of rearticulation--in the middle of the tautomorphemic geminate [tt] in [ʃattəs].

The larger study reported here confirmed the results of the pilot study. Furthermore, the results suggested that the factor which influenced the durations of the geminates (whether tautomorphemic or heteromorphemic) was the type of phonological boundary crossed rather than the type of

³The possibility that this could also show movement of saliva without rearticulation was suggested to me by Arthur Abramson during the presentation of the results of the pilot study as a poster at the 11th Meeting of the Acoustical Society of America, May 14, 1986. Since this is certainly possible, further investigation is needed in order to determine the cause of the spikes.

morpho-syntactic boundary. This was suggested by the fact that the heterosyllabic geminates (which include both tautomorphemic and heteromorphemic geminates) had similar durations relative to their single counterparts (approximately 2.5:1), while the tautosyllabic geminates (which include both tautomorphemic and assimilated heteromorphemic geminates) had a shorter duration relative to their single counterparts (approximately 2:1).

2. Method

The corpus comprised the three dental consonants which occur in all the positions to be tested: [t, d, and t̥]. The words exemplified six sets of contrast types, with one word type chosen for each relevant consonant in each condition, as shown in Table I below, where X = tested consonant.

The transcription used here and throughout the paper is the International Phonetic Alphabet, except that a dot under the consonants t, d, s, and z (t̥, d̥, s̥, z̥) indicates pharyngealization, and a dot under the consonant h (h̥) indicates a voiceless pharyngeal fricative.

Table I
The Corpus of Words Used

- (A) Initial Single Consonant vs. Initial Assimilated Heteromorphemic, Tautosyllabic Geminate Across A Word Boundary
- (1) Type #C- = XəCC (single consonant; indefinite noun)
 - [təxt] 'a bed'
 - [dərs] 'a lesson'
 - [təbl̥] 'a drumbeat'
 - (2) Type ART#C- = X#XəCC (assimilated heteromorphemic, tautosyllabic geminate; across a word boundary; definite article assimilated to the first consonant of the following noun)⁴
 - /ʔil#təxt/ --> [t#təxt] 'the bed'
 - /ʔil#dərs/ --> [d#dərs] 'the lesson'
 - /ʔil#təbl̥/ --> [t#təbl̥] 'the drumbeat'
- (B) Medial Single Consonant vs. Medial Tautomorphemic, Heterosyllabic Geminate Across a Syllable Boundary
- (3) Type -C- = CəXəC (single consonant; Form I verb)
 - [kətəb] 'to write'
 - [wədəʔ] 'to give up'
 - [bətəl̥] 'to become invalid'

⁴When the definite article /ʔil/ occurs in speech, [ʔil] is generally not pronounced when the preceding word begins with a vowel. In this study it was never pronounced, so it is not included in the phonetic representation.

- (4) Type -C\$C- = CəX\$XəC (tautomorphemic, heterosyllabic geminate; Form II verb = 'causative of Form I')
 [kət\$əb] 'to make someone write'
 [wəd\$dəf] 'to take leave of someone'
 [bət\$əɪ] 'to invalidate'
- (C) Initial Single Consonant vs. Initial Assimilated Heteromorphemic, Tautosyllabic Geminate Across a Morpheme Boundary
- (5) Type #C- = XəCVC (Form I verb)
 [təbɪf] 'to follow'
 [dəθər] 'to be forgotten'
 [tələf] 'to come into view'
- (6) Type #C+REFL+ = X+X+əCəC (assimilated heteromorphemic, tautosyllabic geminate; across a morpheme boundary; Form VIII verb = 'reflexive of Form I'; reflexive morpheme /-t-/ assimilated to the first consonant of the verb)
 /t+t+əbəf/ --> [t+t+əbəf] 'to follow'
 /d+t+əθər/ --> [d+d+əθər] 'to cover oneself'
 /t+t+ələf/ --> [t+t+ələf] 'to be well informed about'
- (D) Initial Single Consonant vs. Initial Heteromorphemic, Heterosyllabic Geminate Across a Word Boundary
- (7) Type #C- = Cə[CəC#XəCC] (single consonant; noun; the phonetic material in brackets matching that in brackets in Condition 8 as closely as possible--since verbs end in a consonant, it was not possible to have a schwa precede the tested consonant in Condition 7 as it does in Condition 8--so that the difference of interest between Conditions 7 and 8 is the length of the initial C of the second word)
 [ʃənəb#təxt] 'He warded off a bed.'
 [zəhəm#dərs] 'He jostled a lesson.'
 [həbəɪs#təbl] 'He apprehended a drumbeat.'
- (8) Type C#C- = [CəCəX#XəCC] (heteromorphemic, heterosyllabic geminate; across a word boundary; Form I verb#noun)
 [nəbət#təxt] 'He sprouted a bed.'
 [həməd#dərs] 'He praised a lesson.'
 [bəɪsət#təbl] 'He offered a drumbeat.'
- (E) Final Single Consonant vs. Final Tautomorphemic, Tautosyllabic Geminate Across No Word Boundary
- (9) Type -C# = CV(C)[CV:X#ɪl#CəCC] (single consonant; noun#definite

⁵This contrast occurs only for [d], [t], and [t] because these are the only consonants which the reflexive morpheme -t- assimilates to totally when it is infixated after the first consonant of the verb. Hence, this study investigated only these three consonants.

article#noun; the phonetic material in brackets matching that in brackets in Condition 10 as closely as possible--including matching the stress on the first word in 10 with a long vowel in 9--so that the difference of interest is the length of the final consonant of the first noun)⁶

- [rufæ:t#Il#kəlb] 'the remains of the dog'
 *{?Il#ħa:d#Il#xərb} 'the graves of the war'
 *{?Il#ʕa:t#Il#kəlb} 'the noises of the dog'

- (10) Type -CC# = [CəXX#Il#CəCC] (tautomorphemic, tautosyllabic geminate; noun#definite article#noun)
 [fətt#Il#kəlb] 'the weakening of the dog'
 [ħedd#Il#xərb] 'the limiting of the war'
 [ʕətt#Il#kəlb] 'the dipping of the dog'

(F) Final Single Consonant vs. Heteromorphemic, Heterosyllabic Geminate Across a Word Boundary

- (9) Type -C# = [CV(C)CV:X]#Il#CəCC (single consonant; noun#definite article#noun; the phonetic material in brackets matching that in Condition 11)
 [rufæ:t#Il#kəlb] 'the remains of the dog'
 *{?Il#ħa:d#Il#xərb} 'the graves of the war'
 *{?Il#ʕa:t#Il#kəlb} 'the noises of the dog'
- (11) Type -C#C = [CV(C)CV:X]#XəCC (heteromorphemic, heterosyllabic geminate; across a word boundary; noun#indefinite noun)
 [rufæ:t#təxt] 'remains of a bed'
 *{?Il#ħa:d#dərb} 'the graves of a pass'
 *{?Il#ʕa:t#təbl} 'the noises of a drumbeat'

Five tokens of each word were written on separate index cards, grouped into the two categories A + B + C, and D + E + F, and randomized within categories by shuffling. One native speaker of Levantine Arabic from the pilot study participated in this experiment. Before beginning the experiment, he was asked to read through the words on the cards to make sure he could read them, and he received the same instructions as in the pilot study, written in Arabic and reproduced in (3) in English.

- (3) "Place each of the following words in the blank space in the following sentence: [ʔulna _____ mərre tæ:ni] 'We said _____ again.' Read the sentence as if you were speaking with a good friend."

When the native speaker had finished reading, the experimenter told him again, for emphasis, to be sure to say each written word as he would in his usual speech at home. Then he sat in an anechoic chamber to carry out the

⁶Two phrases in which the first definite article is ungrammatical--marked by *--were included in order to facilitate the phonetic matching.

⁷As in Condition 9 (see Note 6), two phrases in which the first definite article is ungrammatical--marked by *--were included in order to facilitate the phonetic matching.

experiment and was recorded as he read the sentences. A spectrogram was made of each sentence, and the length of each tested consonant was measured to the nearest half millimeter.

3. Results and Discussion

Spectrograms showed that, as in the pilot study, release spikes were sometimes present within the duration of both the tautomorphemic and the heteromorphemic geminates. Not surprisingly, they were found in two types of unassimilated heteromorphemic geminates: one consonant geminated initially across a word boundary (Type C#C-, [bəsa:t#təbl]), and one consonant geminated finally across a word boundary (Type -C#C, [ʔil#ʔa:t#təbl]). However, they were also found in two types of assimilated heteromorphemic geminates (which are said to have a tautomorphemic type of structure and therefore not to be separable): one consonant geminated with the assimilated definite article (Type ART#C-, [d#dərs]), and one consonant geminated initially with the assimilated reflexive morpheme (Type #C+REFL+, [t+t+ələʃ]). Furthermore, they were found in one type of tautomorphemic geminate: two final tautomorphemic geminates (Type -CC#, two instances of [ʔət:t]). The spectrogram in Figure 2 shows one of the tokens with a release spike present within the duration of the tautomorphemic geminate.

All of these spikes appear to indicate some sort of rearticulation within the duration of the consonant--whether a heteromorphemic or a tautomorphemic geminate. These results confirm the spectrographic results of the pilot study that spikes did not distinguish the heteromorphemic geminates from the tautomorphemic geminates since they occurred during the

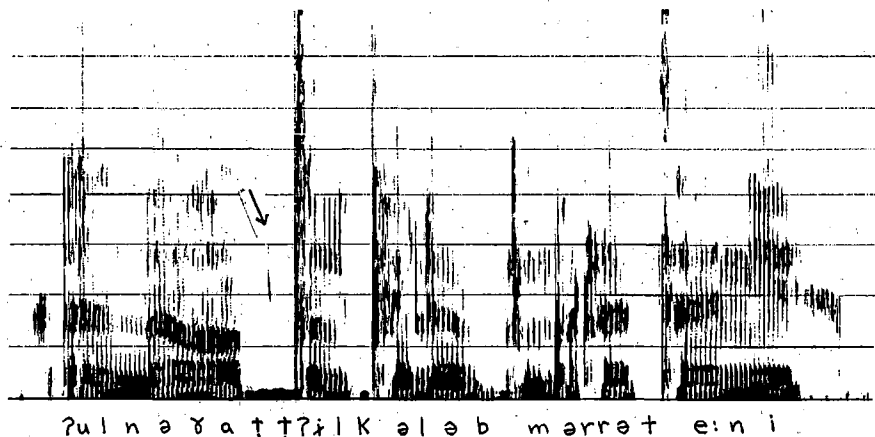


Figure 2. An apparent release spike--which may be evidence of rearticulation--within the duration of the tautomorphemic geminate consonant [t:t] in [ʔət:t ʔil kələb].

closure durations of both. This suggests that if there is a phonetic difference between the two types of geminate consonants it must be something other than the presence or absence of a release within the consonant duration.

The instances of apparent rearticulation in the heteromorphemic geminates across a word boundary were not surprising because phonological studies have shown that the individual consonants of heteromorphemic geminates can be separated. However, the instances in the final tautomorphemic geminates and in the heteromorphemic geminates assimilated with the definite article and with the reflexive morpheme were surprising since phonological studies have given evidence that the individual consonants in these types of geminates are never separated. These results also suggest the possibility that the individual consonants of tautomorphemic geminates and assimilated heteromorphemic geminates are less closely joined than the phonological studies suggest since the consonant duration can be interrupted in the middle by a spike, like heteromorphemic geminates, whose individual consonants are treated phonologically as not joined to each other at all. As in the pilot study, this hypothesis cannot be taken as conclusive since a spike occurred only two times in the middle of both a tautomorphemic geminate and an assimilated heteromorphemic geminate in this study and since this study did not find any spikes in the medial tautomorphemic geminates (Type -C#C-) as the pilot study did. However, this is an interesting occurrence worthy of further investigation.

To examine whether there were differences in duration between heteromorphemic and tautomorphemic geminates, the average duration of the five tokens of the geminate consonant and the five tokens of the single consonant for each word pair was calculated. Then the ratios of the average duration of each geminate consonant to the average duration of the corresponding single consonant were computed. The results of these calculations are shown in Figure 3. The figure shows that, as in the pilot study, all the consonants differing in quality in this study were treated in the same way within the same morphological condition since the ratios [tt]:[t], [dd]:[d], and [ʃʃ]:[ʃ] were nearly the same within every condition. This was confirmed by a 6X3 ANOVA which showed that Consonant was not a significant main effect ($F=0.91$, $p=0.4070$, $df=2$).

ANOVAs were also run on the data to compare Consonant by Condition for the average duration of each consonant. The results of these tests are shown in Figure 3, which indicates that, contrary to the pilot study, the geminate consonants in this study were treated differently in different morphological conditions since the ratios differ substantially among the conditions. This was confirmed by the 6X3 ANOVA, which showed that Condition was a significant effect ($F=11.73$, $p<0.0001$, $df=5$), while the interaction between Consonant and Condition was not significant ($F=0.67$, $p=0.7462$, $df=10$).

Figure 3 also shows that two of the three sets of geminates with the same morphological structure--unassimilated and assimilated heteromorphemic geminates--were treated in the same way since the ratios for the former (C#C- and -C#C) and for the latter (#C+REFL+ and ART#C-) were similar. On the other hand, Figure 3 shows that the two types of geminates with tautomorphemic structure were treated differently from each other since the ratios for -CC# and -C#C- differ substantially.

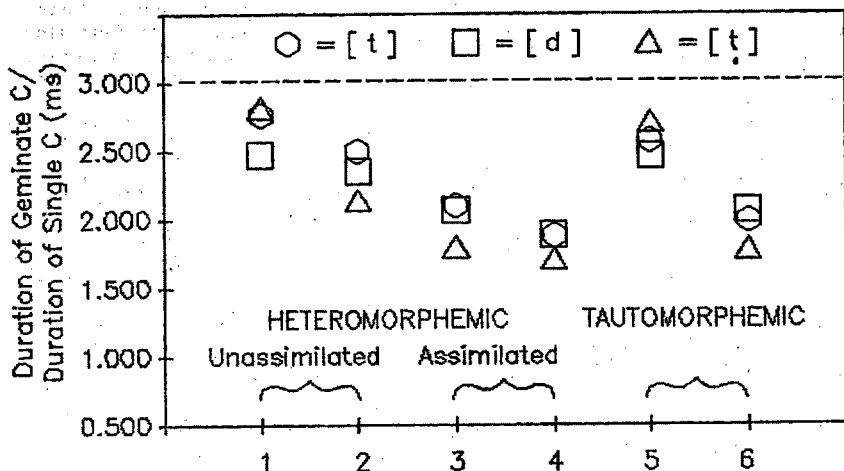


Figure 3. Ratios of the average duration of the geminate consonants to the average duration of the corresponding single consonants, arranged to show the values for heteromorphic geminates on the left and for tautomorphic geminates on the right.

- | | | |
|---------------|------------------|----------------|
| 1 = C#C-/#C- | 3 = #C+REFL+/#C- | 5 = -C\$C-/-C- |
| 2 = -C#C-/-C# | 4 = ART#C-/#C- | 6 = -CC#/-C# |

Therefore, while this analysis shows that all three of the consonants tested were treated somehow in the same way, it does not show what this was. It shows that (1) the unassimilated heteromorphic geminates in this study were all treated the same--as predicted by phonological theory, (2) the assimilated heteromorphic geminates were treated the same as each other but differently from the unassimilated geminates--also as predicted by phonological theory, and (3) the tautomorphic geminates were not all treated the same: the medial tautomorphic geminates were treated like the unassimilated heteromorphic geminates, while the final tautomorphic geminates were treated like the assimilated heteromorphic geminates.

The random pattern just described in result (3) is not as predicted by phonological theory, which says that tautomorphic geminates and assimilated heteromorphic geminates pattern together as opposed to unassimilated heteromorphic geminates. Phonological theory does not say that there are different types of tautomorphic geminates, each of which patterns with a different type of heteromorphic geminate, as this study found. These results therefore seem to indicate another type of pattern which has not been identified by phonological theory--a pattern of phonetic difference between geminates with some sort of different structure, but not between the classes of heteromorphic geminates and tautomorphic geminates.

To verify the significance of the differences shown in Figure 3, four post-hoc ANOVAs were done to compare the four conditions in this experiment whose environments were matched phonetically as closely as it was possible

to do so, since statistics would be the most reliable for these. These conditions were the ones whose tested consonants were preceded by (and also usually followed by) the same or nearly the same segments and stress patterns. These conditions, along with the results of the ANOVAs, are listed in Table II.

Table II
Comparison of Conditions which were Closely Matched Phonetically

- (A) A significant difference ($F=14.20$, $p=0.0009$, $df=1$) was found between (1) the ratio of Type -CC# to Type -C# and (2) the ratio of Type -C#C to Type -C#.

- (1) Type -CC# = [CəXX#Iɪ#CəCC] (Condition 10 in Table I)
e.g., [fətt#Iɪ#kəlb] 'the weakening of the dog'

Type -C# = CV(C)[CV:X#Iɪ#CəCC] (Condition 9 in Table I)
e.g., [rufə:t#Iɪ#kəlb] 'the remains of the dog'

The ratio of the duration of final geminates to the duration of final single consonants was computed from these types. In this contrast, the phonetic material immediately preceding each pair of tested consonants (in brackets) was matched as closely as possible by matching the stress on the first word in Type -CC# with a long vowel in Type -C#. The phonetic material following each pair of tested consonants (also in brackets) was matched exactly.

- (2) Type -C#C = [CV(C)CV:X]#XəCC (Condition 11 in Table I)
e.g., [rufə:t#təxt] 'remains of a bed'

Type -C# = [CV(C)CV:X]#Iɪ#CəCC (Condition 9 in Table I)
e.g., [rufə:t#Iɪ#kəlb] 'the remains of the dog'

The ratio of the duration of geminates across a word boundary to the duration of final single consonants was computed from these types. In this contrast, the phonetic material preceding each pair of tested consonants (in brackets) was matched exactly, while the material following the tested consonants (not in brackets) differed.

- (B) A significant difference ($F=14.18$, $p=0.0010$, $df=1$) was found between (1) the ratio of Type C#C- to Type #C- and (2) the ratio of Type #C+REFL+ to Type #C-.

- (1) Type C#C- = [CəCəX#XəCC] (Condition 8 in Table I)
e.g., [nəbət#təxt] 'He sprouted a bed.'

Type #C- = Cə[CəC#XəCC] (Condition 7 in Table I)
e.g., [ʃənəb#təxt] 'He warded off a bed.'

The ratio of the duration of geminates across a word boundary to the duration of initial single consonants was computed from these types. In this contrast, the phonetic material in brackets in both of these conditions was matched except that the tested single consonants could not be preceded by a schwa, as the tested geminate consonants were, because verbs in Levantine Arabic end in consonants. Both types of tested consonants were, however, preceded by unstressed syllables.

- (2) Type #C+REFL+ = X+X+əCəC (Condition 6 in Table I)
e.g., /t+t+ələʃ/ → [t+t+ələʃ] 'to be well informed about'

Type #C- = XəCVC (Condition 5 in Table I)
e.g., [tələʃ] 'to come into view'

The ratio of the duration of initial geminates assimilated across a morpheme boundary to the duration of initial single consonants was computed from these types. In this contrast, both the preceding and the following phonetic material was matched exactly, except that the second vowel after one of the tested single consonants ([t]) was [I], while all the other vowels were [ə].

- (C) A significant difference ($F=19.88$, $p=0.0002$, $df=1$) was found between (1) the ratio of Type C#C- to Type #C- and (2) the ratio of Type ART#C- to Type #C-.

- (1) Type C#C- = [CəCəX#XəCC] (Condition 8 in Table I)
e.g., [nəbət#təxt] 'He sprouted a bed.'

Type #C- = Cə[CəC#XəCC] (Condition 7 in Table I)
e.g., [ʃənəb#təxt] 'He warded off a bed.'

The ratio of the duration of geminates across a word boundary to the duration of initial single consonants was computed from these types. In this contrast, the phonetic material in brackets in both of these conditions was matched except that the tested single consonants could not be preceded by a schwa, as the tested geminate consonants were, because verbs in Levantine Arabic end in consonants. Both types of tested consonants were, however, preceded by unstressed syllables.

- (2) Type ART#C- = X#XəCC (Condition 2 in Table I)
e.g., /ʔIl#təxt/ → [t#təxt] 'the bed'

Type #C- = XəCC (Condition 1 in Table I)
e.g., [təxt] 'a bed'

The ratio of the duration of initial geminates assimilated across a word boundary to the duration of initial single consonants was computed from these types. In this contrast,

the phonetic material both preceding and following the tested consonants was matched exactly.

- (D) No significant difference ($F=2.46$, $p=0.1302$, $df=1$) was found between (1) the ratio of Type #C+REFL+ to Type #C- and (2) the ratio of Type ART#C- to Type #C-.

- (1) Type #C+REFL+ = X+X+əCəC (Condition 6 in Table I)
e.g., /t+t+ələ/ → [t+t+ələ] 'to be well informed about'

Type #C- = XəCVC (Condition 5 in Table I)
e.g., [tələ] 'to come into view'

The ratio of the duration of initial geminates assimilated across a morpheme boundary to the duration of initial single consonants was computed from these types. In this contrast, the phonetic material both preceding and following the tested consonants was matched exactly, except that the second vowel after one of the tested single consonants ([t]) was [ɪ], while all the other vowels were [ə].

- (2) Type ART#C- = X#XəCC (Condition 2 in Table I)
e.g., /tɪl#təxt/ → [t#təxt] 'the bed'

Type #C- = XəCC (Condition 1 in Table I)
e.g., [təxt] 'a bed'

The ratio of the duration of initial geminates assimilated across a word boundary to the duration of initial single consonants was computed from these types. In this contrast, the phonetic material both preceding and following the tested consonants was matched exactly.

The statistics given in Table II support the conclusions which were drawn by inspection of Figure 3. They confirm that the differences between three of the higher and lower CC:C ratios (shown by the higher peaks and the lower peaks) in Figure 3 are significant, while the differences between two of the lower peaks are not significant. Although the statistical significance or insignificance of the other differences shown in Figure 3 cannot be verified directly since any other comparisons involve material that is not matched phonetically, it can be assumed by analogy to the tested differences that the other large differences are probably significant, while the small differences are probably not significant. This assumption should, of course, be tested by further study.

In addition, a t-test run on the two geminates of different type whose environments were matched completely (-CC# and -C#C) provides further evidence that the lengths of these geminates were significantly different. It showed that for types -CC# (tautomorphemic, tautosyllabic) and -C#C (heteromorphemic, heterosyllabic) the absolute values of their mean durations--and not just their ratios--differed significantly. Figure 4 shows this clearly since each consonant of the type -C#C is substantially longer than the same consonant of the type -CC#. The other geminates in

this study could not be accurately tested this way since none of their environments were matched totally.

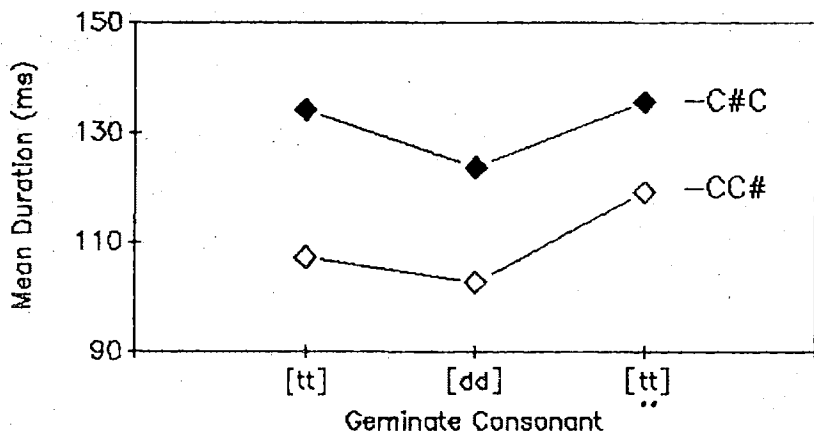


Figure 4. Mean durations of geminates in exactly the same environments (-CC# and -C#C), showing that the absolute values of their mean durations--and not just their ratios--differed significantly.

If the durational differences shown in Figure 3 are reliable, then, how do we account for the fact that the tautomorphic geminates do not exhibit the same behavior for this characteristic--contrary to the predictions of current phonological theory, while the unassimilated and assimilated heteromorphic geminates do--as predicted by current theory? Furthermore, why does one of the tautomorphic geminates (-CC#) pattern with the assimilated heteromorphic geminates--as current theory predicts--and the other tautomorphic geminate (-C#C-) pattern with the unassimilated heteromorphic geminates--the opposite of what is predicted? It is clear that something besides the morpheme structure is involved in determining the pattern of durational differences.

What the two different groups have in common within themselves and different from each other is syllable structure. The unassimilated heteromorphic geminates and the tautomorphic geminate which patterns with them are heterosyllabic; that is, the geminates are part of two syllables. On the other hand, the assimilated heteromorphic geminates and the tautomorphic geminate which patterns with them are tautosyllabic--they are part of only one syllable.

Figure 5 shows clearly the type and extent of phonetic difference that was found between the different types of geminates in this study. It gives a comparison of the means for the ratios of all the geminate consonants to their single counterparts, and it shows that the conditions which pattern together--three on the left and three on the right--do not have morpheme structure in common. That is, geminates within a word which cross only a

syllable boundary (Type -C\$C-) pattern with geminates which cross a word boundary but are not formed by assimilation with the definite article (Types C#C- and -C#C), while the other types of geminates within a word (Types -CC#--across no boundary--and #C+REFL+--assimilated across a morpheme boundary) as well as geminates assimilated across a word boundary with the definite article (Type ART#C-) pattern differently from these and similarly to each other. Specifically, the ratios for consonants geminated across a syllable boundary within a word were more similar to the ratios for consonants which were geminated across a word boundary than they were to other consonants which were geminated either within a word or assimilated with the definite article.

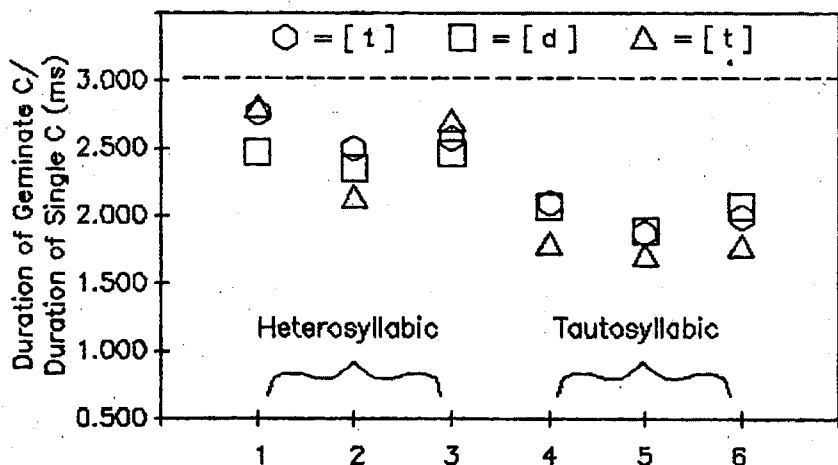


Figure 5. Ratios of the average duration of the geminate consonants to the average duration of the corresponding single consonants, as in Figure 3, but here arranged to show the values for heterosyllabic geminates on the left and tautosyllabic geminates on the right.

1 = C#C-/#C-

3 = -C\$C-/ -C-

5 = ART#C-/#C-

2 = -C#C/-C#

4 = #C+REFL+/#C-

6 = -CC#/-C#

This makes it obvious that the factor which conditioned the phonetic difference found in this study was not morpho-syntactic. Rather, it was phonological (more specifically, prosodic) since the three conditions which pattern together on the left in Figure 5 are heterosyllabic while the three which pattern together on the right are tautosyllabic. Specifically, crossing a syllable boundary--whether within a word or across words--resulted in a longer geminate (approximately 2.5 times the length of the single counterpart) than not crossing a syllable boundary did (approximately 2.0 times the length of the single counterpart).

Figure 5 also shows that durational differences did not distinguish tautomorphic geminates from heteromorphic geminates in this study since the former (Types -C\$C- and -CC#) had different average durations in

comparison to their single counterparts. The consonants of Type -C\$C- were approximately 2.5 times the length of their single counterparts--like the other consonants which were geminated across a syllable boundary, but the consonants of Type -CC# were approximately 2.0 times the length of their short counterparts--like the other consonants which were geminated in contexts other than across a syllable boundary.

4. Conclusions

This investigation has found some evidence that for this Levantine Arabic speaker there is no significant phonetic difference between heteromorphemic and tautomorphemic geminate consonants in terms of either duration or distinctive release within the duration. This agrees with the results obtained by the previous study which specifically tested such geminates in Turkish and Bengali--Hankamer and Lahiri (1986). It also agrees with the previous phonological studies which claim that there are no phonetic differences between these types of geminates. Furthermore, the absence of a difference in these types of geminates in this investigation suggests that what have previously been termed "long consonants" in phonetic studies because they do not cross any morpho-syntactic boundary (here called "tautomorphemic geminates") should more properly be termed "geminates" as is done in phonological studies since several of them in this study had spikes on their spectrograms in the middle of their durations, as did several of the consonant clusters (here called "heteromorphemic geminates"). If confirmed by further research that these spikes are evidence of rearticulation, this would provide evidence for a phonetic argument that all of the lengthened consonants investigated here are clusters of two like segments--geminates of some sort, based on the previous studies which found rearticulation to often be a characteristic--or even the defining characteristic--of geminate consonants.

Furthermore, this investigation has found that for this speaker of Levantine Arabic there is a significant difference between heterosyllabic and tautosyllabic geminates in terms of ratio to their single counterparts, and--by implication--duration (verified for one of the sets of geminates in the study). Although to my knowledge this type of geminate structure has not been tested before, these results agree with the general claims of previous phonetic studies that there are phonetic characteristics which differentiate different types of geminates. Furthermore, these results suggest that in order to investigate whether there are phonetic differences between different types of geminates--and to discover what they are--geminates must be investigated at a different level of structure from that which they have been so far. The level of investigation must be syllable (prosodic) structure, rather than either morpheme structure or word structure--since, as described in Section 1, the phonetic differences between geminates of different morpheme or word structure claimed by some of the previous phonetic studies were not found consistently by all the studies or all the time by any of the studies. This finding confirms the hypothesis of this study that whatever phonetic differences exist consistently between geminates are likely manifested at the surface level of structure rather than at any abstract level.

This investigation has also added to our knowledge of the details of the characteristics of geminates in the areas of consonant duration and

movement during the duration. The results on duration generally agreed with the results of most of the previous studies: for this speaker of Levantine Arabic all types of geminate consonants were about twice as long as the corresponding single consonants. Therefore, this study did not find evidence that heteromorphemic and tautomorphemic geminates ever differed significantly in duration, as suggested by some of the data from two previous studies (Delattre 1971; Lehiste, Morton, and Tatham 1973). However, this investigation provided new information on heterosyllabic and tautosyllabic geminates, finding that they differed in duration. The former were approximately 2.5 times the length of their single counterparts, while the latter were approximately 2.0 times the length of their single counterparts, whether or not these different syllabic types crossed morpho-syntactic boundaries.

Furthermore, since the investigation reported here found apparent release spikes on some of the spectrograms of both heteromorphemic and tautomorphemic geminates, these results on movement during consonant duration agreed with the results of the group of previous studies which suggested that there is some movement during the duration of both types of geminates (since these studies found both heteromorphemic and tautomorphemic geminates to generally have two or more peaks in their air pressure curves, articulatory pressure curves, or EMG traces) (see Section 1). The results of this study therefore did not support the group of previous studies which suggested that heteromorphemic geminates generally exhibit some movement during their durations (since they generally had two peaks in their amplitude curves and tongue shapes), while tautomorphemic geminates do not exhibit movement during their durations (since they had only one peak in these curves) (see Section 1). Furthermore, since this study suggests that both of these types of geminates may have the characteristic of movement during their durations, it shows that terming them both geminates (rather than long consonants vs. geminate consonants as many of the previous phonetic studies did) may have a phonetic basis as well as a phonological basis, since they can both apparently be interrupted during their durations. It also suggests that the individual consonants of tautomorphemic geminates and assimilated heteromorphemic geminates may be less closely joined than the phonological studies suggest since the consonant duration can be interrupted in the middle by a spike, like heteromorphemic geminates, whose individual consonants are treated phonologically as not joined to each other at all.

However, since the apparent release spikes found here occurred in only a few instances--far less frequently than the indications of movement occurred in previous studies--these can be only tentative conclusions. It may be that the consonants investigated here differ from those investigated previously or that the previous tests used more powerful measures and so could record finer movements than this test could. Other types of tests would be needed on Levantine Arabic in order to decide among these possibilities. Further research needs to be done with more speakers; all the consonants of Arabic; air pressure, amplitude, and EMG recordings; and x-ray recordings of tongue shape.

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